

SELECTED TOPICS IN OVERSET TECHNOLOGY DEVELOPMENT AND APPLICATIONS AT NASA AMES RESEARCH CENTER

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**Invited presentation at the 6th Symposium on Overset Composite Grids
& Solution Technology, Ft. Walton Beach, FL, October 8-10, 2002**



OUTLINE

- Overview of overset activities at NASA Ames**
- Recent developments in Chimera Grid Tools**
- A general framework for multiple component dynamics**
- A scripting approach to automating liquid rocket sub-systems simulations**
- Critical future work for overset technology**

OVERSET ACTIVITIES AT NASA AMES

Development

- Chimera Grid Tools (Chan, Rogers)
 - PEGASUS 5 (*Suhs, Rogers, Dietz*)
 - OVERFLOW chemistry (Olsen, et al.)
 - INS3D multi-level parallelism (Kiris)
 - XML4CFD (Mурman, Chan, Attosmis, Meakin)
 - AerODB (Rogers, Attosmis, Tejnil, Ahmad, Pandya, ...)
 - ASG auto surface gridding (Klopfеr, Onufеr) [restart FY03?]
- I
- OVERFLOW-D (Meakin, Potsdam)
- A

Applications

- Liquid rocket engine subsystems (Kiris, Chan, Kwak)
 - Liquid Glide Back Booster under AerODB (Chaderjian)
 - Cardiovascular system – assist devices, arteries (Kiris, Kwak)
 - Harrier in ground effect (Chaderjian, et al.) [not active]
- I
- Rotorcraft (Meakin, Potsdam, Strawn, Dimanlig, ...)
 - Missiles (Meakin, Nygaard)
- A

IMPLEMENTATION OF CHEMISTRY IN OVERFLOW

Collaborators: M. Olsen, S. Venkateswaran, D. Prabhu, T. Olsen, Y. Liu, M. Vinokur

Premixed Equilibrium Chemistry

- N-S eq. with arbitrary eq. of state, element ratio constant over space and time
- computation speed comparable with perfect gas

General (Non-Premixed) Equilibrium Chemistry

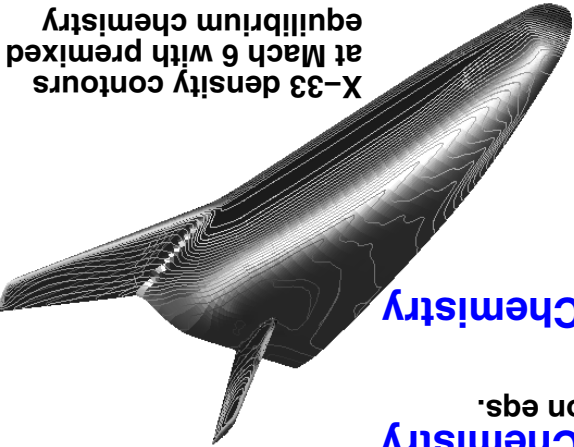
- N-S, species convection, equilibrium composition eqs.
- robust reacting capability

Computationally Efficient Finite Rate Chemistry

- N-S, species convection, rate eqs.
- general reacting flow capability

Features

- general thermodynamic model (not tied to a particular functional form)
- computational efficiency
- general mixtures of perfect gases



X-33 density contours at Mach 6 with premixed equilibrium chemistry

Papers to be presented at 41st AIAA Aerospace Sciences Meeting & Exhibit, Jan., 2003.

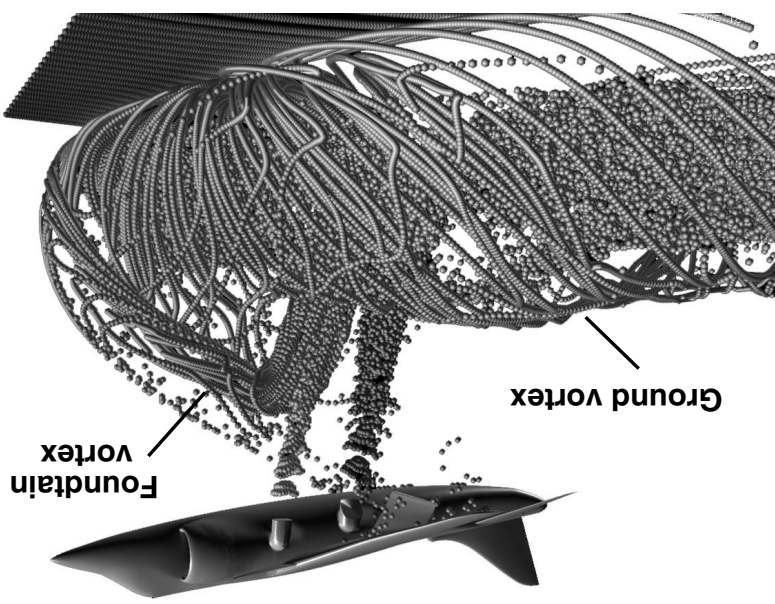
Olsen, M. E., Liu, Y., Vinokur, M. and Olsen, T., Implementation of Premixed Equilibrium Chemistry Capability in OVERFLOW, AIAA Paper 2003-0962.

Olsen, M. E., Venkateswaran, S., Prabhu, D. K. and Olsen, T., Implementation of Finite Rate Chemistry Capability in OVERFLOW, AIAA Paper 2003-0963.

- 35 time accurate RANS solutions (4 million pts) in 1 week using OVERFLOW (952 dedicated Origin processors, AIAA 2002-3056)
- captured low frequency oscillations (0.5 Hz)
- captured unsteady flow structures
- developed Dbview GUI for local/remote access of database

Results

- reduce process time to generate database
- demonstrate ability to capture unsteady flow structures & frequency



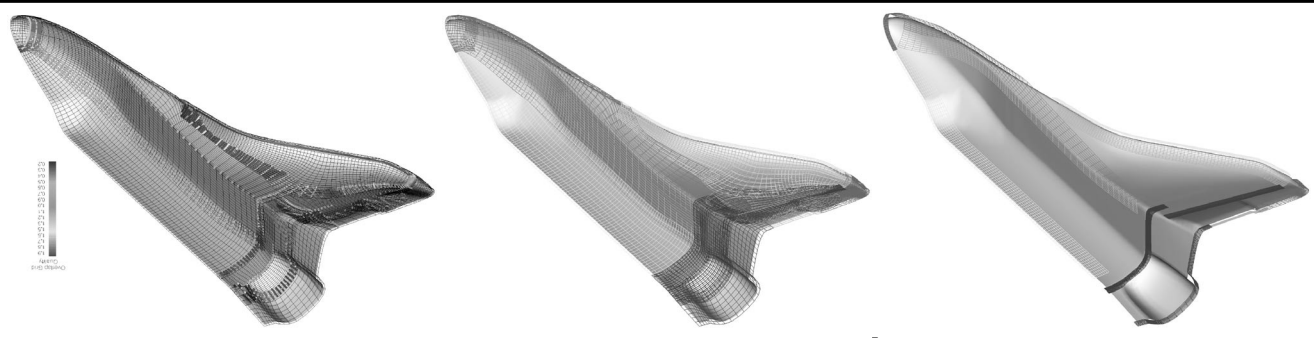
Objectives

- hot gas ingestion
- suck-down effect
- ground personnel

Motivation: Safety

Collaborators: N. Chaderjian, J. Ahmad, S. Pandya, S. Murman

HARRIER UNSTEADY DATABASE GENERATION



- re-adjusts grid generator inputs based on grid quality
- iterate until grid quality criteria are satisfied

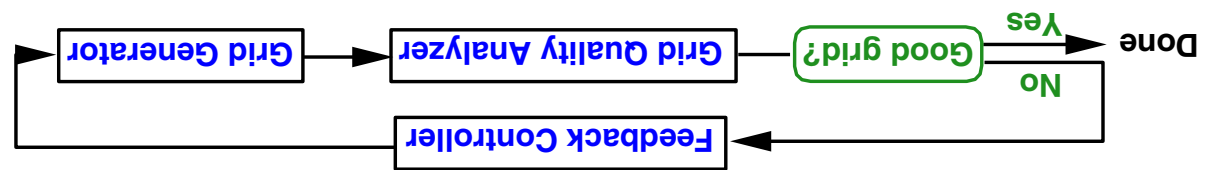
Feedback Controller

- single grid (grid-induced truncation error)
- overlap grid (relative volume, cell-difference, stencil quality)

Grid Quality Analyzer

- SURGRD hyperbolic/algebraic surface grid generator

Grid Generator



Collaborators: Goetz Klopfer, Jeff Onufer (restart FY 03 ?)

ASG AUTOMATIC SURFACE GRIDDING

RECENT DEVELOPMENTS IN CGT

Version 1.7 released in July, 2002

Main new features in OVERGRID

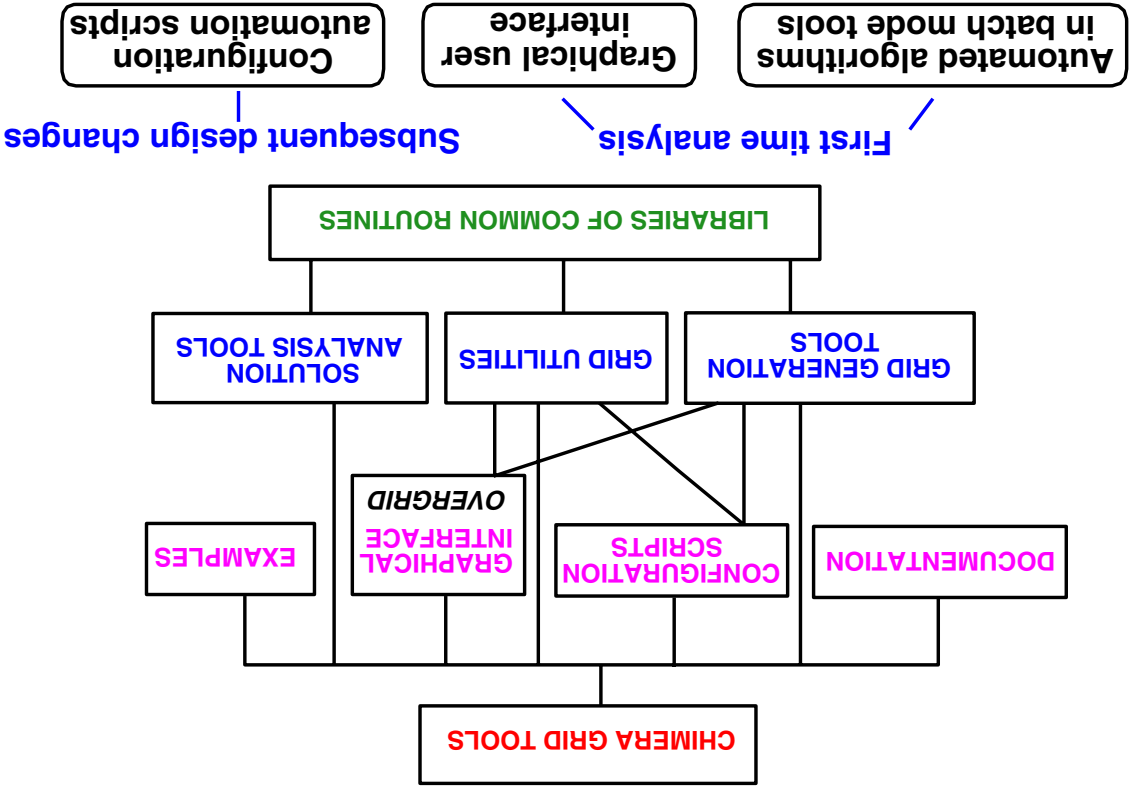
- Advanced diagnostics
- Auto boundary conditions selection and display
- OVERFLOW-D function calls
- Component hierarchy and dynamics module
- Faster I/O and reduction on peak memory requirement

Recent publications at 32nd AIAA Fluid Dynamics Conference, St. Louis, Missouri, June, 2002

Chan, W. M., The OVERGRID Interface for Computational Simulations on Overset Grids, AIAA Paper 2002-3188.

Chan, W. M., Gomez, R. J., Rogers, S. E. and Buning, P. G., Best Practices in Overset Grid Generation, AIAA Paper 2002-3191

Suhs, N. E., Rogers, S. E. and Dietz, W. E., PEGASUS 5: An Automated Pre-processor for Overset-Grid CFD, AIAA Paper 2002-3186

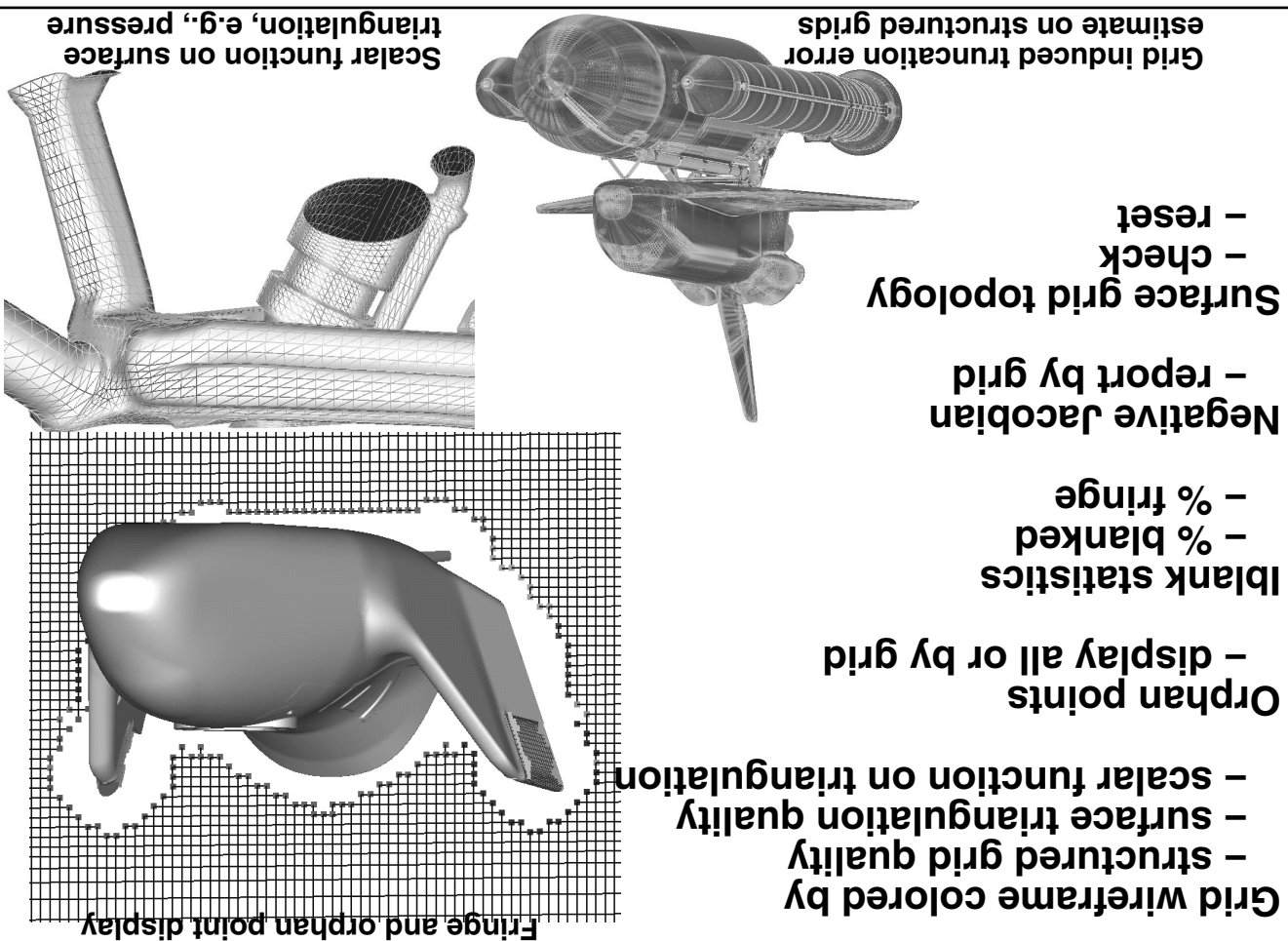


Objective – reduce overall Chimera CFD analysis time

**Collaborators: William Chan, Stuart Rogers,
Steve Nash, Pieter Buning, Bob Meakin**

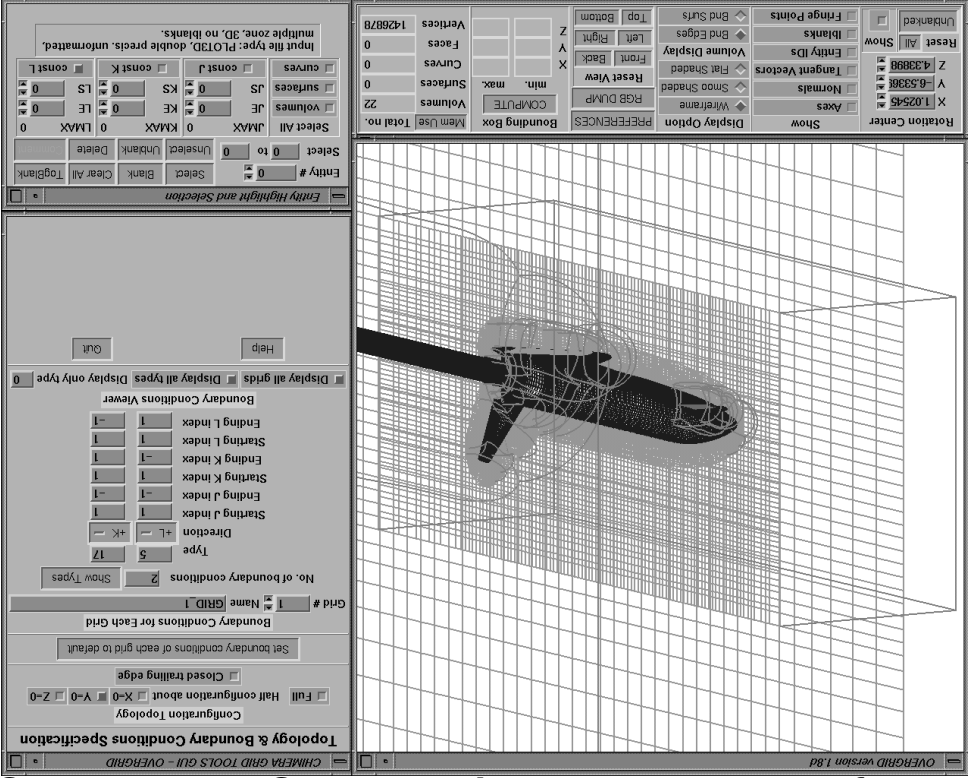
CHIMERA GRID TOOLS (CGT)

OVERGRID'S MAIN WINDOWS (version 1.9)



AUTO BOUNDARY CONDITIONS SELECTION AND DISPLAY

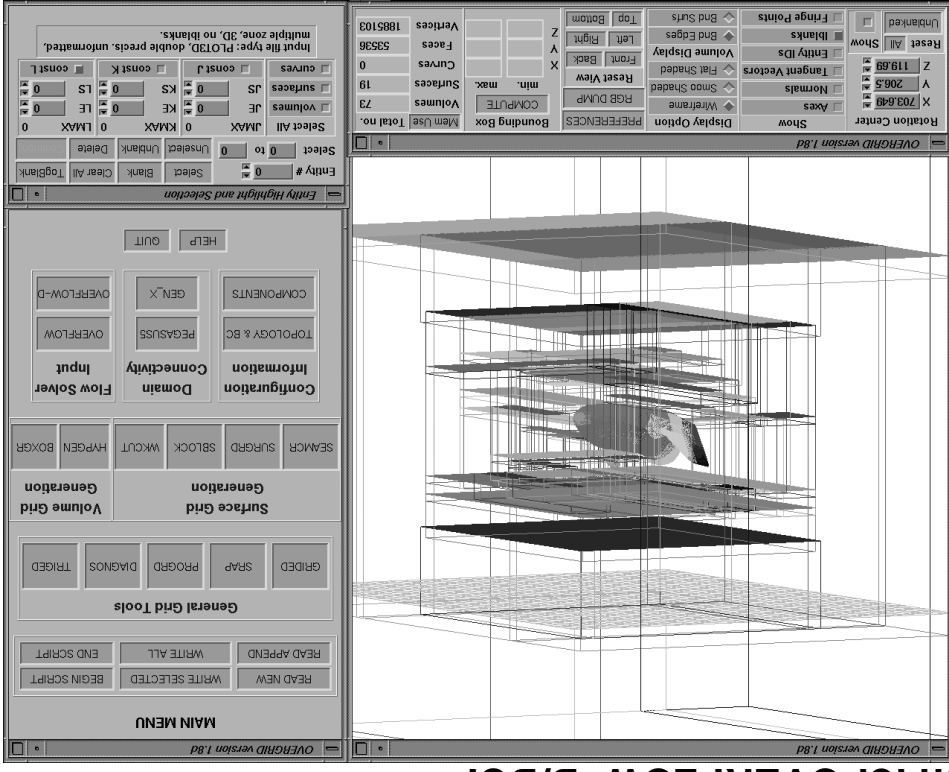
- Auto selection of topological and wall boundary conditions
- Widgets for fast manual override if needed
- Surfaces colored by b.c. type for quick visual check
- Very fast flow solver input for large number of grids



Orange = symmetry
Dark blue = viscous
wall
Green = periodic
Magenta = wake cut
Total of 48 b.c.
types supported

OFF-BODY CARTESIAN GRID GENERATION AND DOMAIN CONNECTIVITY USING OVERFLOW-D

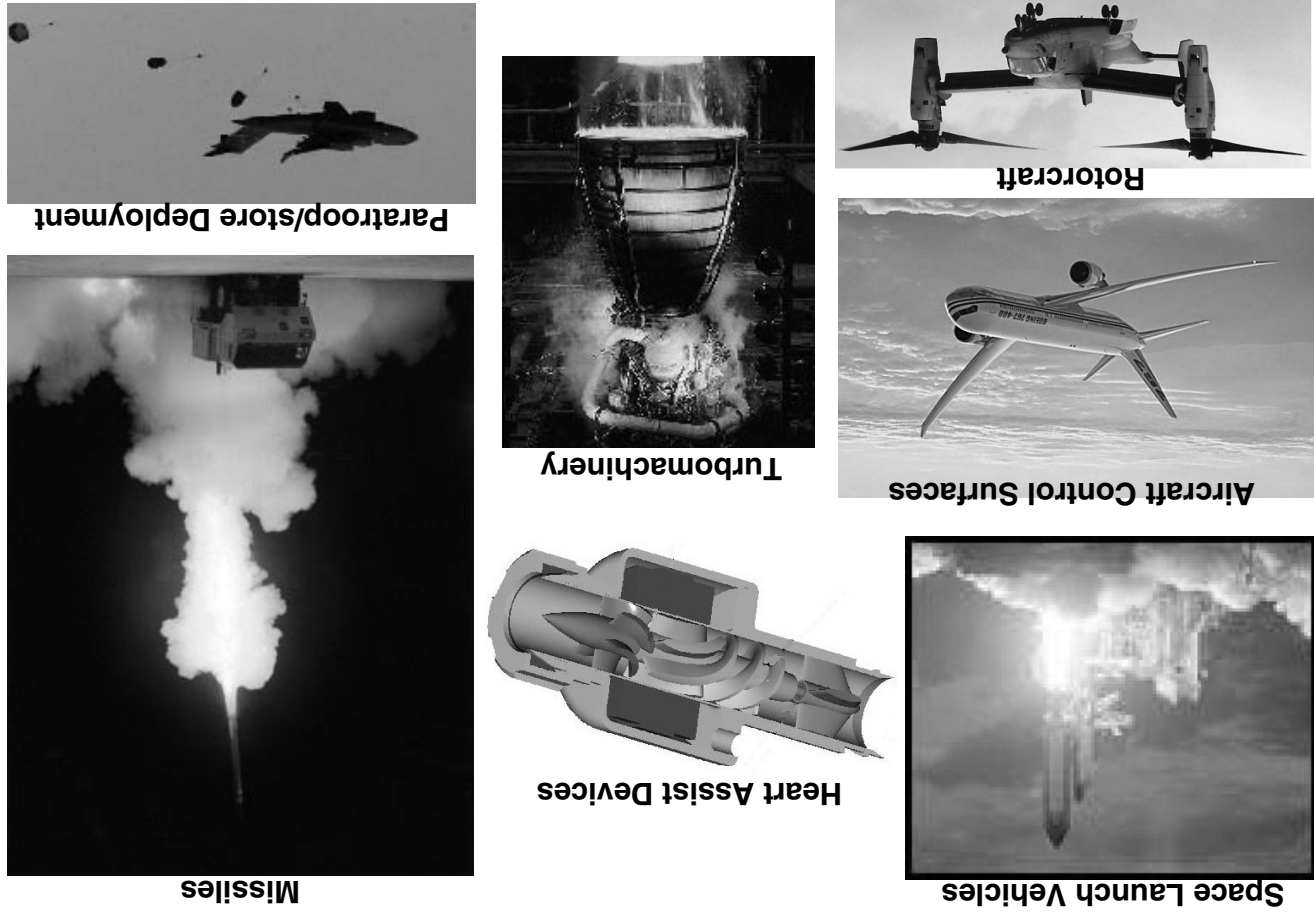
- Module for auto multi-level off-body Cartesian grid generation
- Module for creating object X-rays for hole cutting
- Module for specifying hole cutting information and input creation for OVERFLOW-D/DCF



TO-DO LIST FOR CHIMERA GRID TOOLS

- More robust hybrid surface grid generation tool (quads and triangles) for forces and moments computation
- Surface grid generation time reduction
 - > More automatic surface curve creation
 - > More automatic domain decomposition
 - > OVERGRID interface for ASG algorithm/software
- Surface grid generation on CAD – investigate CAPRI interface
- More coordination between graphical interface and scripts
- Approx. 80 other items for improvements to CGT and oversight technology

A SAMPLE OF APPLICATIONS WITH MULTIPLE COMPONENTS IN RELATIVE MOTION



A FRAMEWORK FOR MULTIPLE COMPONENT DYNAMICS

**Collaborators: Scott Murman, William Chan,
Mike Attosmis, Bob Meakin**

Motivation

- Computations involving multiple complex bodies in relative motion have been scarce mainly because
 - > intensive CPU time required
 - > problem definition is difficult and not standardized
- Potential benefit for a variety of NASA and DOD programs

Objective

- Develop common framework that can be used by different kinds of flow solvers (structured or unstructured)
 - OVERFLOW-D** (structured oversight)
 - FLOWCART** (unstructured Cartesian)

Approach

- Use XML files as information exchange format between GUI (for problem setup) and flow solvers
- Develop API for reading/writing the XML files (XML4CFD)
- (C and f90 versions)

FRAMEWORKS

Configuration

- Components hierarchy and relationship to grids, geometry, virtual surfaces, etc.

Scenario

- Rigid-body dynamics of components
 - > prescribed motion
 - > motion under aerodynamic loads
 - unconstrained 6-dot
 - constrained
 - controlled

Configuration Space

- A set of configurations defined by parameterizing certain attributes of a baseline configuration (e.g., a space launch vehicle with a range of elevon settings)

CONFIGURATION FRAMEWORK



- A configuration is a collection of rigid components
- Each component is allowed one immediate parent and can move relative to its parent
- A root component has no parent and can move relative to other root components under an inertial coordinate system
- A component can be of type **struc**, **tri** or **container**
- **Struc** and **tri** components can have associated geometry/grids
- A component can be moved to its initial position via a set of transforms (a prescribed sequence of rotation, translation, and mirror commands)



```
<Component Name="Body flap" Parent="Orbiter" Type="struc">
  <Data><Grid List="9, 11-13" /></Data>
  <Transform>
    <Rotate Center="90.0,0.0,0.0" Axis="0.0,1.0,0.0" Angle="10"
    </Transform>
  </Transform>
</Component>
```

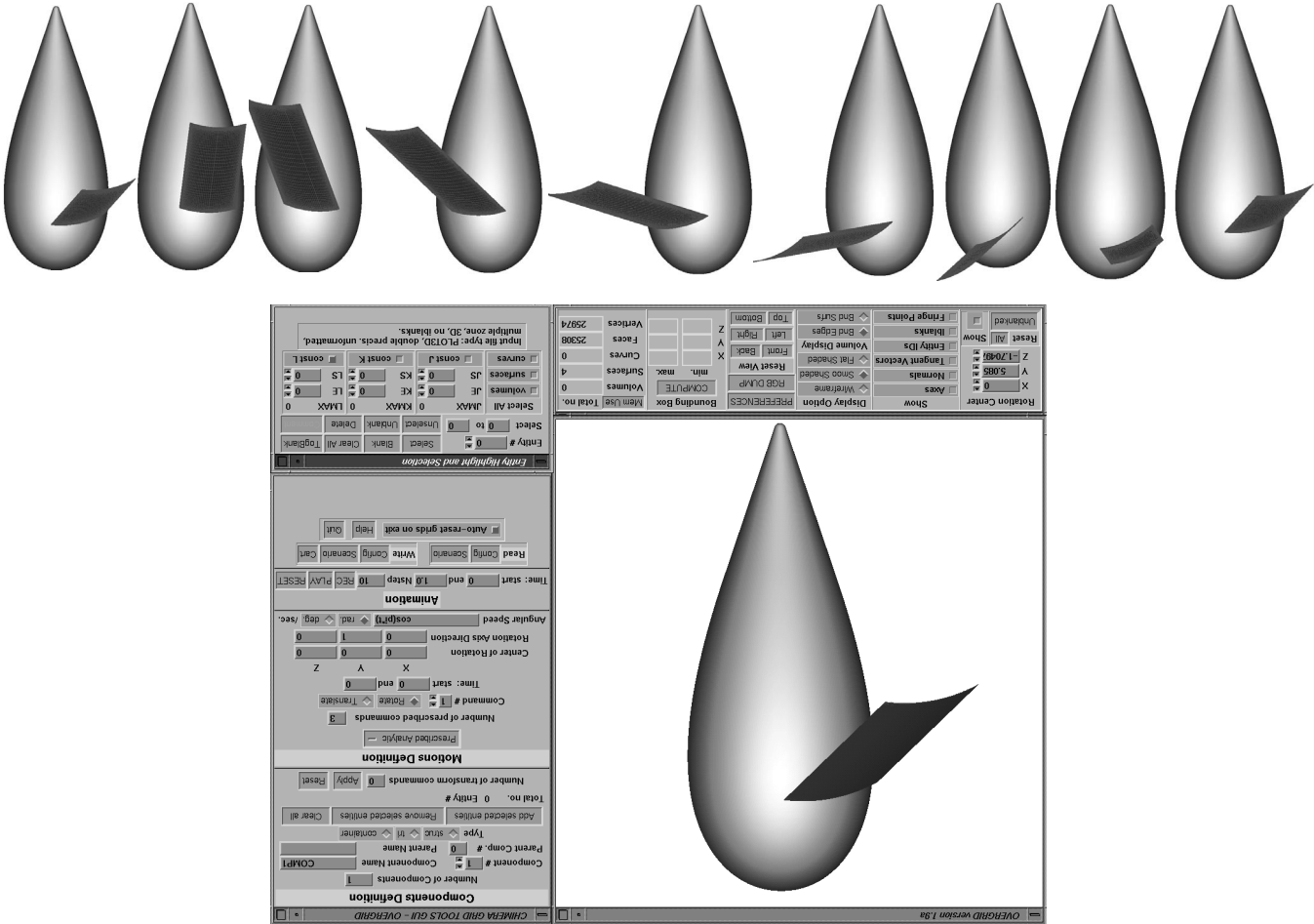
SCENARIO FRAMEWORK

- A scenario is a collection of **prescribed** or **aerobdof** motions
- Each prescribed or aerobdof motion describes the dynamics of a component over a period of time
- Each component may have different motions during different periods of time
- Each prescribed motion is a sequence of rotations and translations over a time period where the velocity components and angular speeds can be arbitrary functions of time

```
<Prescribed Component="Orbiter" Start="0.0" End="1.0">
  <Translate Velocity="0.0, 0.0, 3.0*sqrt(2)" />
  <Rotate Center="0.5,0.0,1.0" Axis="0.0,1.0,0.0" Speed="sin(0.5*pi*t)" />
</Prescribed>
```

- Each aerobdof motion requires the input of the component's
 - > mass and center of mass
 - > moments of inertia and directions of principal axes
 - > external forces and moments (gravity, etc.)
 - > constraints

DEMONSTRATION OF FLAPPING WING IN SCOOPING MOTION



CURRENT STATUS AND FUTURE PLANS

Current status

OVERGRID – specification and animation of components hierarchy and dynamics for prescribed motion, read/write XML files for interfacing with flow solvers

OVERFLOW-D (1.5e) and FLOWCART– read Config and Scenario XML files for driving prescribed motions

Future plans

Config – configuration space, 'clone' component type

Scenario – prescribed motion with table lookup, aerodof motion with constraints, controlled/mixed motions

[More details in paper:](#)

Murman, S. M., Chan, W. M., Aflosmis, M. J., and Meakin, R. L., An Interface for Specifying Rigid-Body Motion for CFD Applications, AIAA Paper 2003-1237, 41st AIAA Aerosciences Meeting and Exhibit, January, 2003.

SCRIPT DEVELOPMENT FOR TURBOPUMP SIMULATIONS

Collaborators: Cetin Kiris, William Chan, Dochan Kwak

Motivation

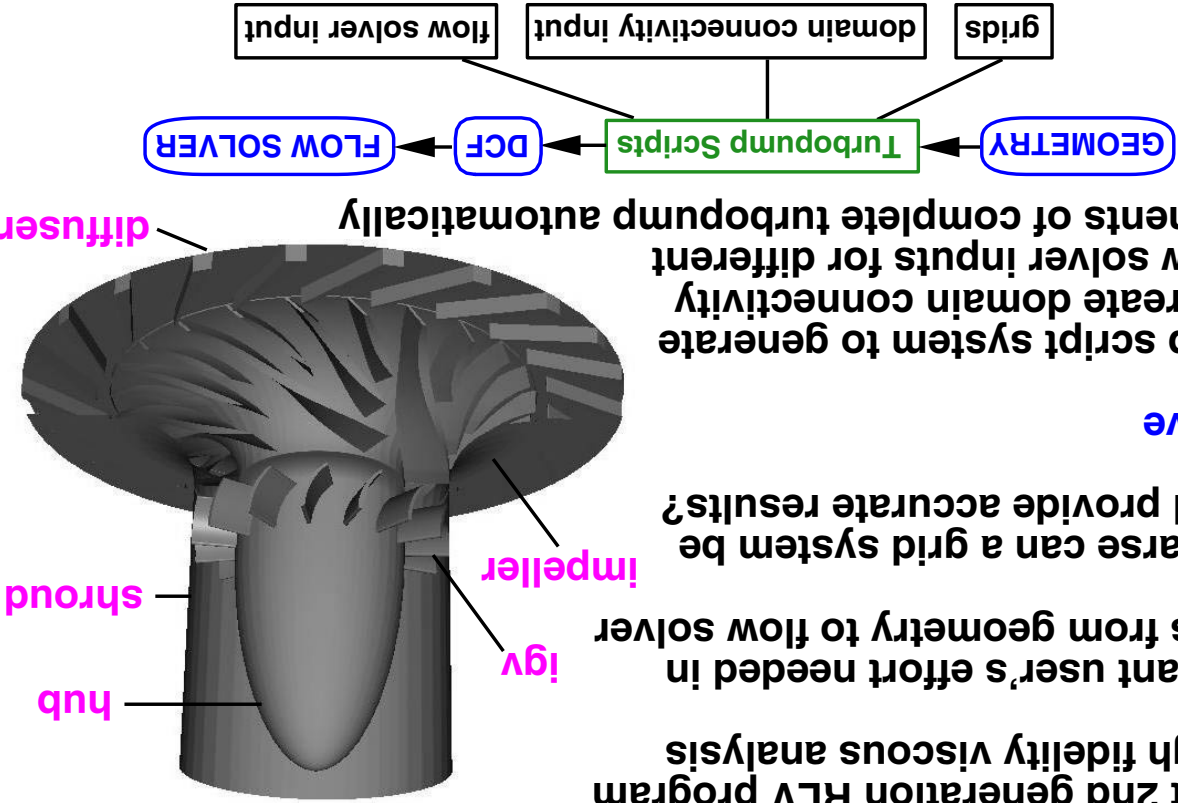
Support 2nd generation RLV program with high fidelity viscous analysis

Significant user's effort needed in process from geometry to flow solver

How coarse can a grid system be and still provide accurate results?

Objective

Develop script system to generate grids, create domain connectivity and flow solver inputs for different components of complete turbopump automatically



General Gridding Strategy

- Create grid system for each component independently and use ring grids for communication between components

First Generation Scripts

- One specialized script for each component with optional rings at inflow and outflow boundaries
- Manual assembly of grids/inputs from different components

Second Generation Scripts

- Single master script that allows the user to specify any combination of components and rings
- Master script calls generic component and ring scripts
- Generic component script can handle geometry for inducer, inlet guide vanes, impeller and diffuser
- Generic ring script can handle ring topology for inflow, outflow, and between components

SCRIPT GENERATION

Disadvantages

- Require expertise to build scripts the first time

Advantages

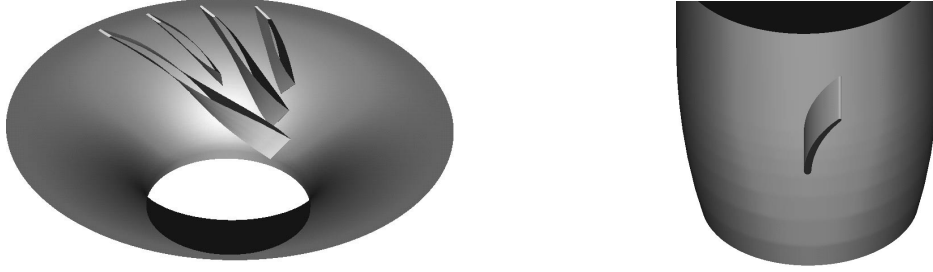
- Allow rapid re-run of entire process
- Easy to do grid refinement and parameter studies
- Easy to try different gridding strategies
- Documentation of gridding procedure

Tcl scripting language

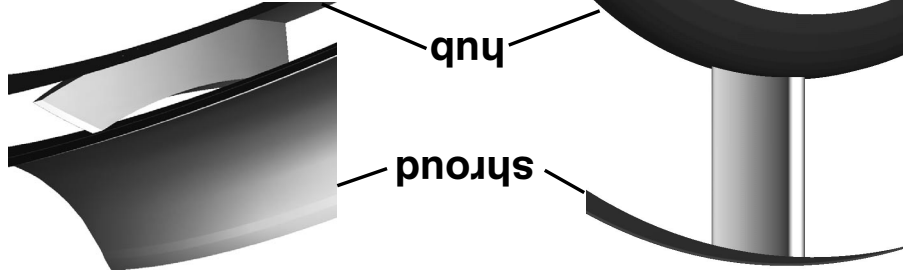
- Works on UNIX, LINUX and WINDOWS
- Integer and floating point arithmetic capability
- Modular procedure calls
- Easy to add GUI later if needed

COMPONENT GEOMETRY PARAMETERS

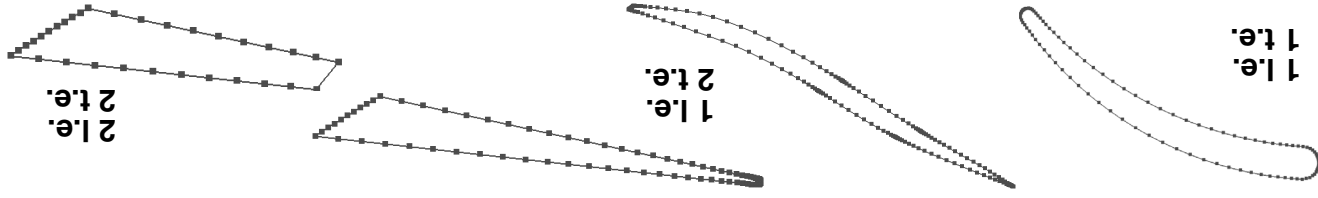
- number of sections and number of distinct blades per section



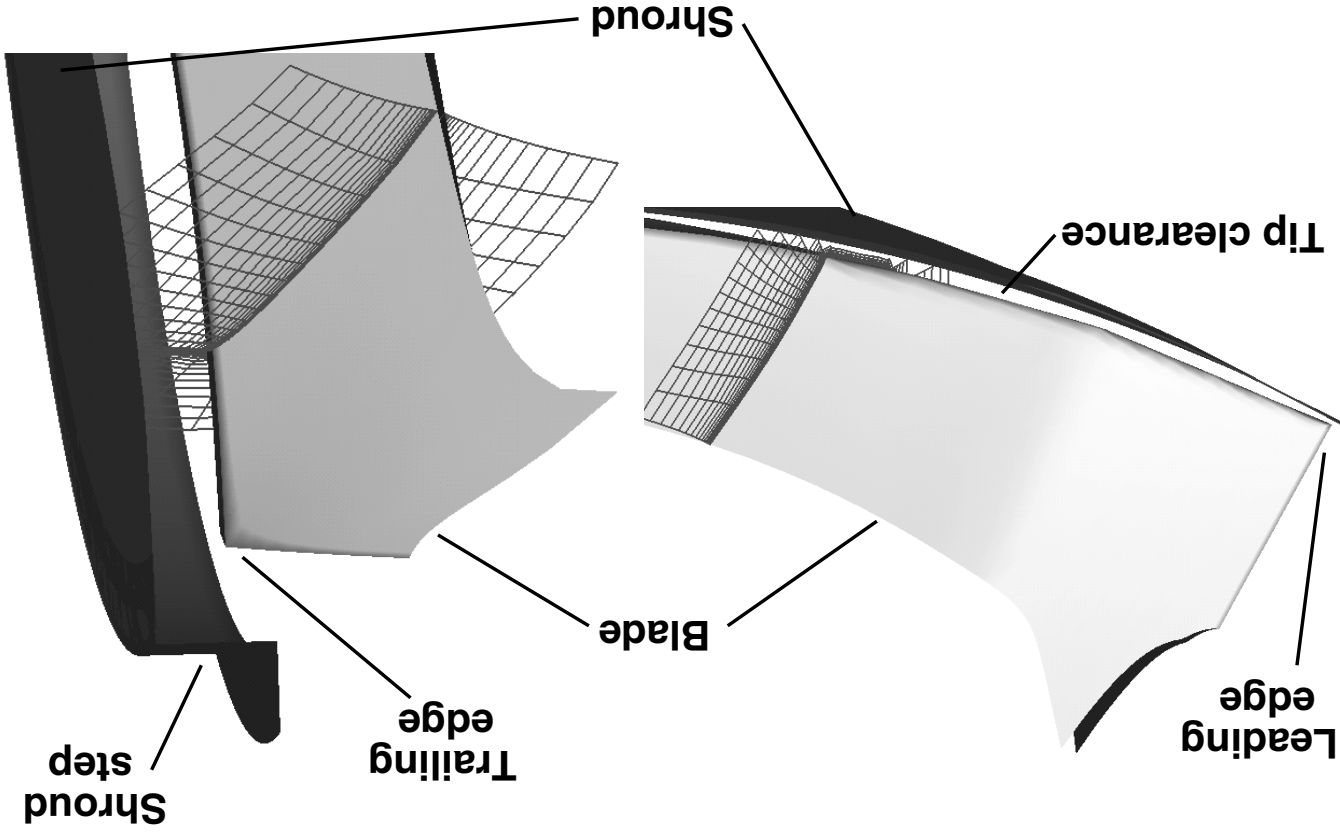
- no tip clearance / tip clearance no step / tip clearance with step



- 1 or 2 control points at blade leading/trailing edges



IMPELLER BLADE TIP CLEARANCE AND SHROUD STEP



INPUT AND OUTPUT

Input

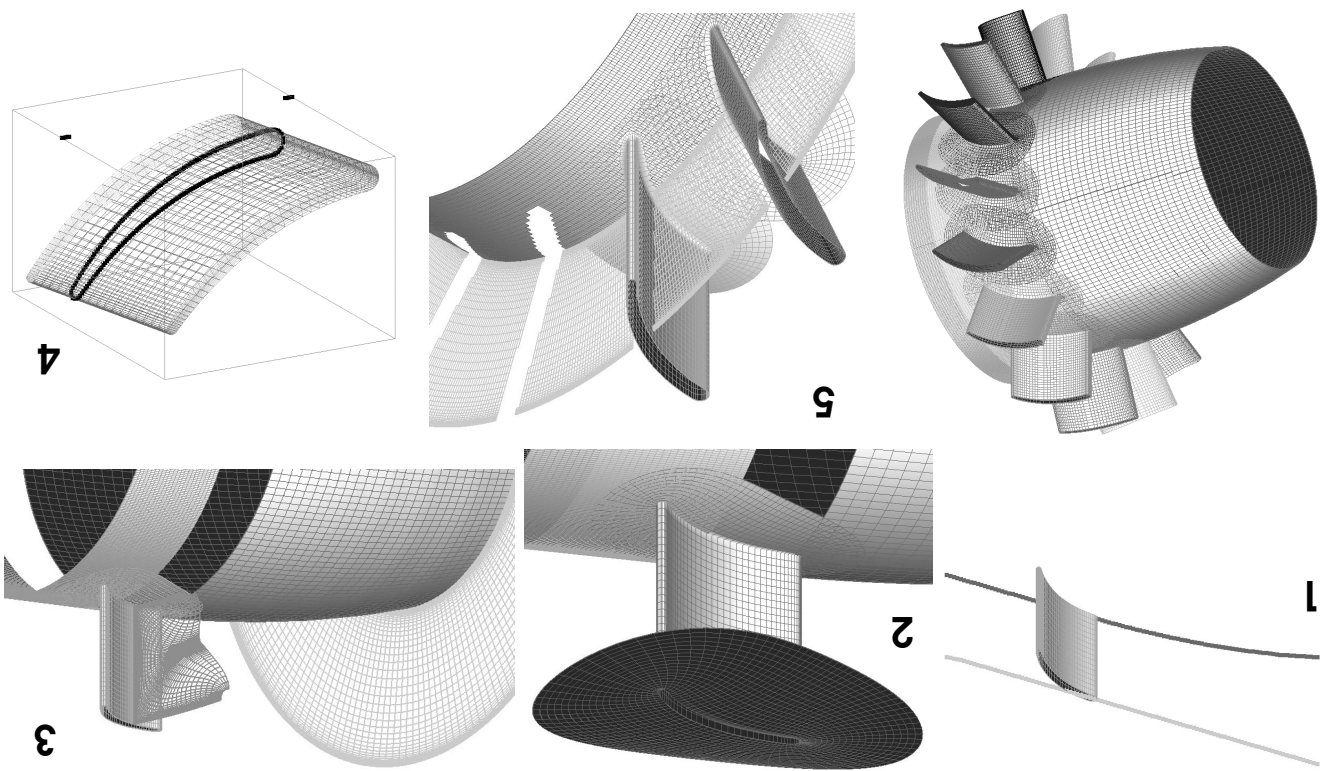
- profile curves for hub and shroud in PLOT3D format (rotated by script to form surface of revolution)
- blade (and tip) surfaces in PLOT3D format

Output

- Parameters that can be changed
- number of blades and sections
- global surface grid spacing Δs_g (on smooth regions)
- local surface grid spacing, some independent (e.g., leading/trailing edge spacing) and some expressed as multiples of Δs_g (e.g., blade span spacing)
- viscous wall normal grid spacing
- marching distances
- grid stretching ratio

- overset surface and volume grids for hub, shroud, blades
- object X-rays for hole cutters using DCF
- domain connectivity namelist input for OVERFLOW-D

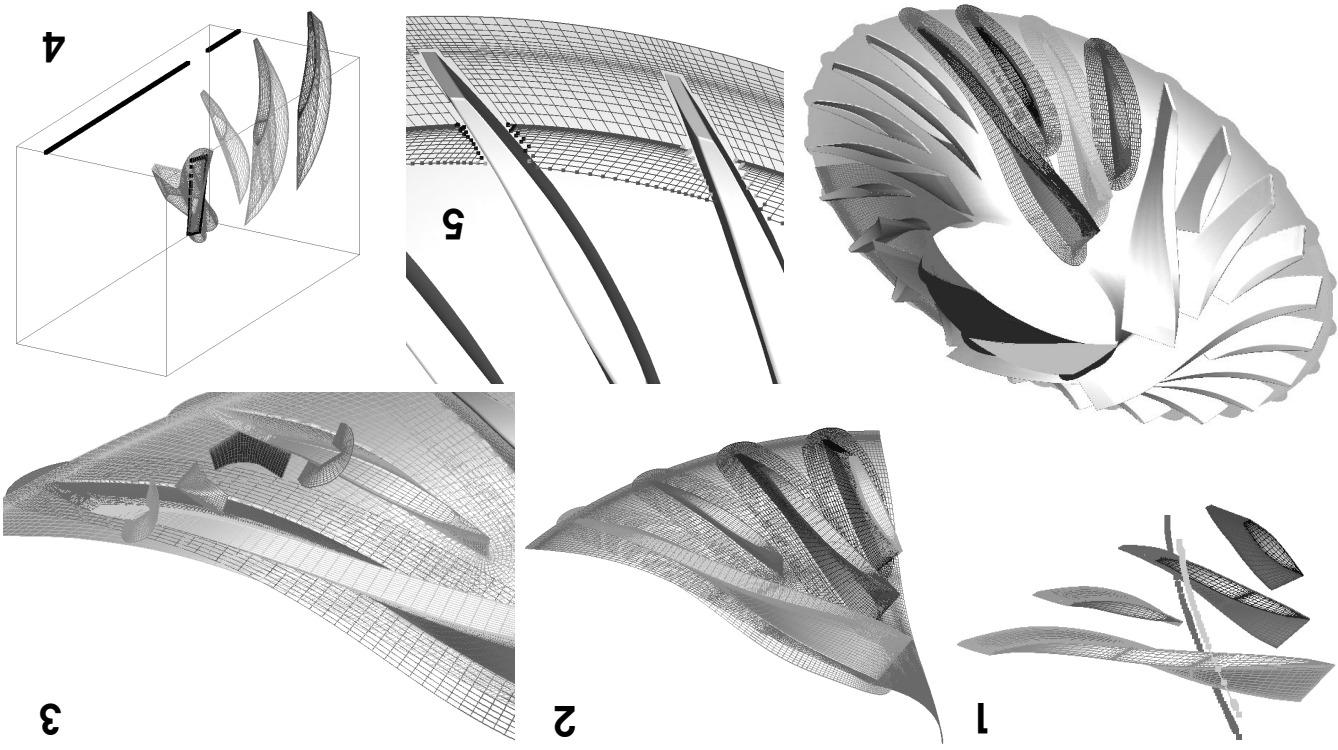
INLET GUIDE VANES (N repeated blades, no tip clearance)



No. of pts (million)	User time *	Manual	Script (fine)	Script (coarse)
7.1	1 day	43 sec.	1.1	20 sec.

(* from geometry def. to DCF input with SGI R12k 300MHz CPU)

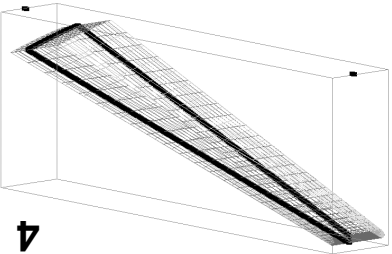
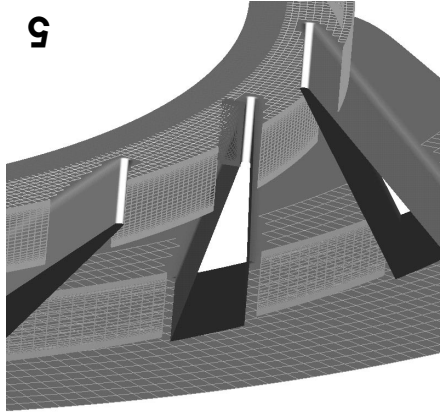
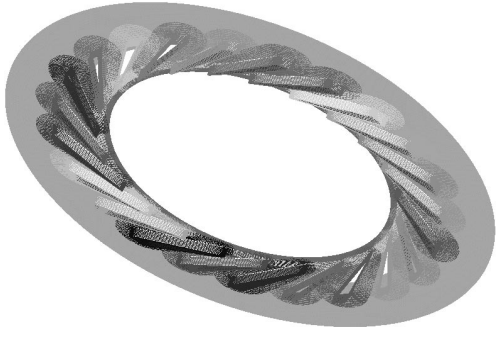
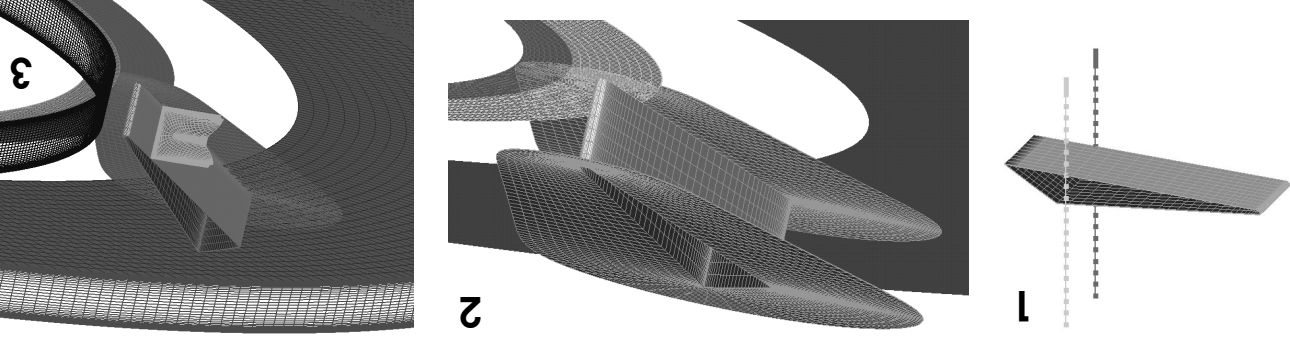
IMPPELLER (M sections, N different blades in each section, tip clearance)



No. of pts (million)	User time *	Manual	Script (fine)	Script (coarse)
19.2	~ 2 weeks	319 sec.	15.2	8.8

(* from geometry def. to DCF input with SGI R12k 300MHz CPU)

DIFFUSER (N repeated blades, no tip clearance)



No. of pts (million)

Manual

Script (fine)

Script (coarse)

User time *

8.0

6.4

1.6

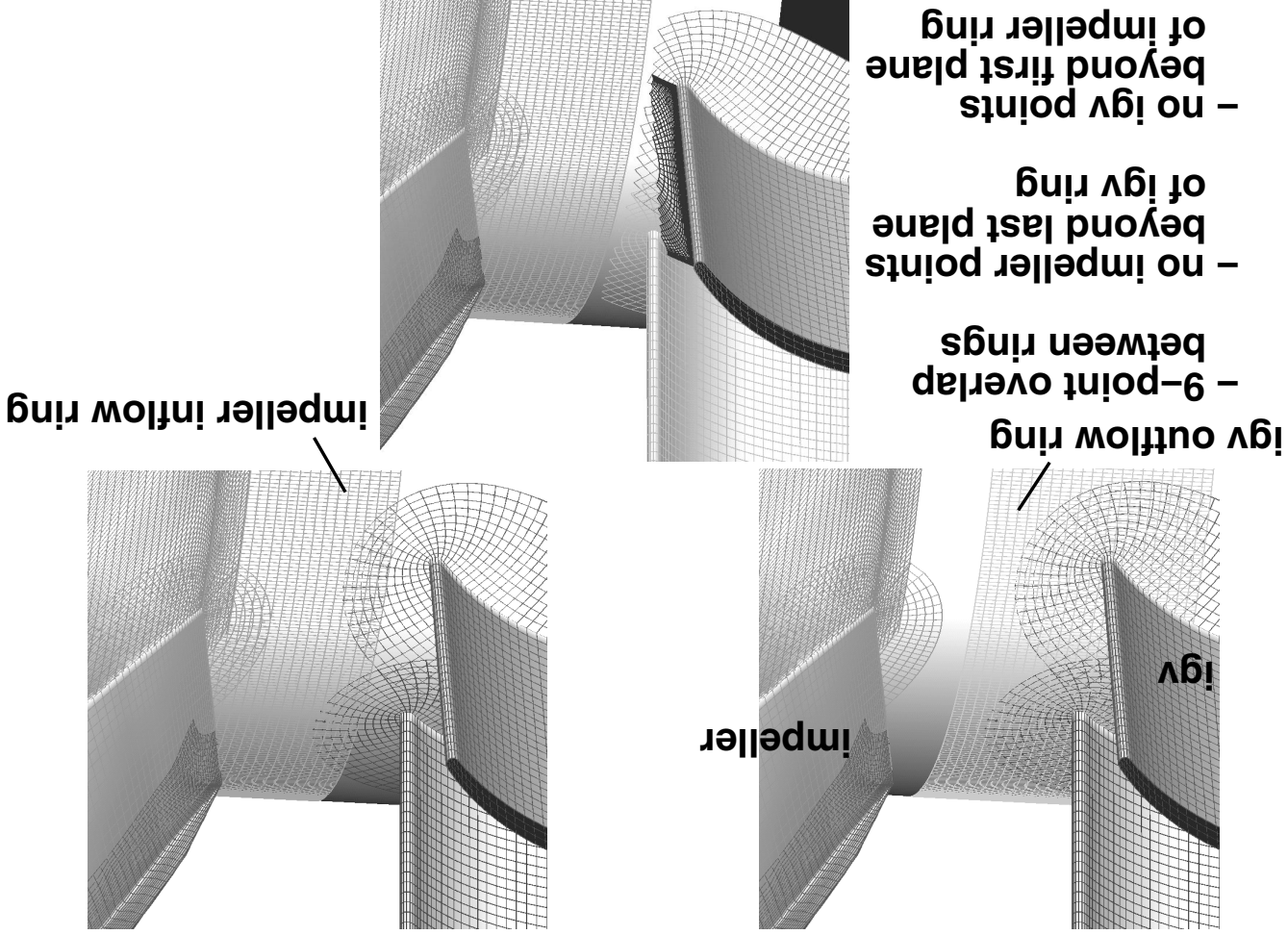
1 day

37 sec.

22 sec.

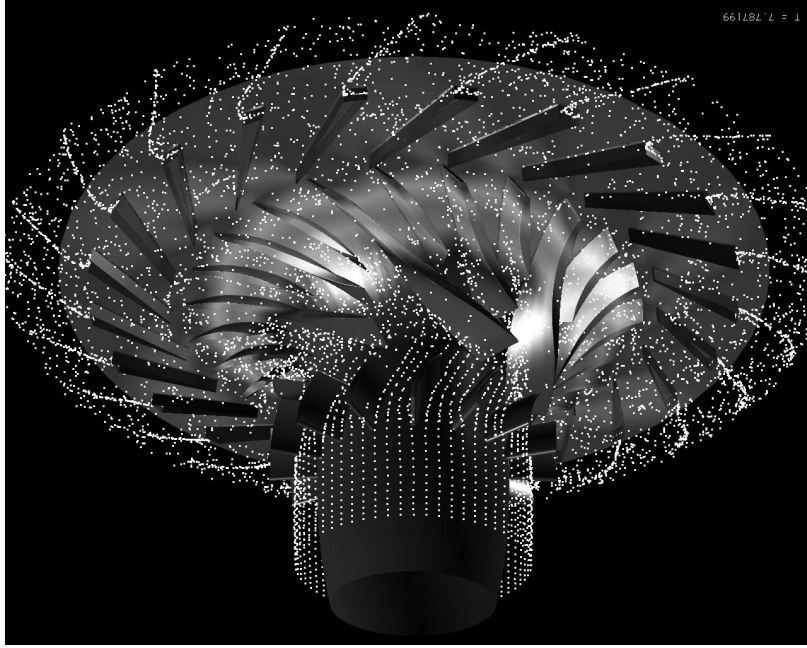
(* from geometry def. to DCF input with SGI R12k 300MHz CPU)

RING INTERFACE BETWEEN COMPONENTS



UNSTEADY COMPUTATIONAL RESULTS

Snapshot of particle traces and pressure surfaces near end of third rotation



Grid system – 34 million points
Wall clock time – 3.5 days/rotation on 128 dedicated Origin
processors using INS3D-MLP

Kiris, C., Chan, W., and Kwak, D., A Three-Dimensional Parallel Time-Accurate Turbopump Simulation Procedure Using Overset Grid Systems, *Proceedings of the 2nd International Conference on Computational Fluid Dynamics*, Sydney, Australia, July 15–19, 2002.

FUTURE PLANS FOR TURBOPUMP SCRIPTING

- Flow solver input creation in scripts
- More input error checks
- Automatic selection of more parameters
- Further robustness improvements
- Perform more tests on different geometry and parameters
- Documentation
- Graphical interface front end

CRITICAL FUTURE WORK FOR OVERSET TECHNOLOGY

In order for oversight technology to gain wider utilization, improvements to the process should be made with the following attributes in mind

Important Critical

Automation	Speed	Robustness	Low user's effort
yes	yes	yes	yes
yes	yes	yes	yes
no	no	no	no
no	no	no	no
e.g., less than about 1 hour's effort on complex geometry			

- Low effort and robust surface grid generation
- surface feature extraction
- surface domain decomposition
- auto-surface coverage (grid resolution matching, overlap optimization)
- Low effort and robust domain connectivity
- hybrid methods
- fast enough for moving-body problems